

ELICITED RESPONDING IN CHAIN SCHEDULES

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An omission procedure was employed to study elicited pecking in the first component of a two-component chain schedule. Both components were fixed-interval schedules correlated with colored keylights. The first response following the initial-link schedule produced a second fixed-interval schedule. We studied several fixed-interval lengths in two conditions: a standard response-dependent condition and an omission-contingent condition. The omission-contingent condition differed from the response-dependent condition in that responses during the initial fixed interval terminated the trial (omitting the terminal component and grain). If the terminal component was not omitted, a response following the terminal link's requirement produced 4-s access to grain. Pigeons responded during more than 70% of the initial links in the omission-contingent condition and responded during more than 90% of the initial links in the response-dependent condition. In general, rates of responding were consistent with the percentage data. The responding in the omission condition suggests that there may be elicited pecking, in chain schedules using pigeons, that is not the result of contingent conditioned reinforcement.

Key words: signal control, chain schedules, elicited pecking, autoshaping, key peck, pigeons

The concept of conditioned reinforcement and the concept of discriminative stimulus are useful to the theoretical understanding of how behavior is sequenced through time. The problem of behavior sequencing considers why some responses follow other responses and what the conditions are that allow us to create a given sequence of responses. Part of the solution to the problem of the sequencing of behavior in the experimental analysis of behavior is accomplished with the concept of behavior chaining, important aspects of which are conditioned reinforcement and discriminative stimuli. Conditioned reinforcement and discriminative stimuli provide connectors or links between responses and explain why responses occur and, also, why they occur in a certain order. In the laboratory, behavior chaining is studied in a procedure called a chain schedule.

In a chain schedule, responses produce a stimulus according to some rule or schedule; in the presence of the stimulus, responses produce reinforcers (Ferster & Skinner, 1957). The schedule and the stimuli that identify the

schedule are called components or links. The stimuli associated with each component of the schedule are said to serve as both a discriminative stimulus for the responses in its presence, setting the occasion for those responses, and as a conditioned reinforcer for the responses that produce the stimulus (Keller & Schoenfeld, 1950; Skinner, 1938). Thus, chaining is a temporal sequence of stimuli and operant responses. Each stimulus in a chain serves simultaneously as a conditioned reinforcer (for the response producing it) and a discriminative stimulus (for the next response required in the chain).

Considering the age of the concept and its prevalence in the analysis of behavior, the empirical support for the concept of conditioned reinforcement is surprisingly controversial (Royalty, Williams, & Fantino, 1987; Staddon, 1972, 1983; B. Williams & Royalty, 1990). Although there are a number of sources of support for the concept of conditioned reinforcement in the chain schedule situation, many can be criticized or interpreted without resort to conditioned reinforcement. Evidence for the value of the conditioned reinforcement concept has come mainly from the comparison of the performances on chain schedules and other schedules that differ only with regard to the stimuli. One comparison is between the performance on a chain schedule and the corresponding tandem schedule, another from a

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comparison of the performance on chain schedules and the corresponding multiple schedules. A tandem schedule is a sequence of schedules identical to a chain schedule except the components are not identified by stimuli. Multiple schedules are sequences of schedules identified by stimuli; these differ from chain schedules in that movement from one schedule to the next occurs independent of responding. The comparisons do not make a convincing argument for the need for conditioned reinforcement. Tandem-chain comparisons often show more pecking in the tandem schedule than in the chain (Wallace, Osborne, & Fantino, 1982); multiple-chain comparisons are often open to interpretations other than one using conditioned reinforcement (Royalty et al., 1987).

There is a further possibility that is the topic of the present experiment: Much of the pecking in chain schedules may be elicited. The discriminative stimuli in chain schedules are paired with grain reinforcers, and the stimuli may come to elicit pecking because of that pairing. Ample evidence, accumulated for years, points to the possibility of elicited key pecking in the chain schedule. There are two types of eliciting procedures that could be implicated: One is autoshaping (Brown & Jenkins, 1968); the other is signal-controlled responding (Lewis & Stoyak, 1979).

In the first reported autoshaping experiment, Brown and Jenkins (1968) exposed naive (and food deprived) pigeons to 160 trials in which an 8-s white keylight was followed immediately by 4-s access to food. The light-food presentations were response independent. Despite the fact that no response was necessary to produce the food, all 36 pigeons began pecking at the lighted key, some in as few as six light-food pairings. D. Williams and Williams (1969), Schwartz and Gamzu (1977), Rescorla (1988), and others have suggested that this pecking behavior is elicited and best understood in terms of respondent conditioning. The keylight becomes a conditioned stimulus (CS) when it is repeatedly paired with the unconditioned stimulus (UCS), food. Pecking becomes a conditioned response (CR), which is elicited by the CS and is directed toward the key.

In an experiment similar to that of Brown and Jenkins (1968), D. Williams and Williams (1969) successfully autoshaped pigeons

using a procedure in which key pecks during the keylight prevented the occurrence of food. Not only was pecking produced, but the pigeons also continued to respond during the keylight and continued to prevent reinforcement. Williams and Williams referred to this phenomenon as negative automaintenance. A response contingency that prevents the occurrence of a reinforcer is sometimes called an omission contingency.

The omission procedure employed by D. Williams and Williams (1969) to demonstrate convincingly the elicited nature of the auto-shaped key peck was also employed to study elicited pecking in an experiment by Lewis and Stoyak (1979). After pigeons acquired key pecking by the method of successive approximations, they were presented with an 8-s tone preceding response-dependent food. Pecking was sustained at high rates even when a response during the tone prevented reinforcement (the omission contingency).

Although most writers have endorsed the elicited response conception of autoshaping and related omission procedures, a few have disputed this analysis (Jenkins, 1977; Locurto, 1981; Moore, 1973). The primary issue for these writers is the logic behind the omission procedures. In the present paper we discuss the results in terms of elicited responding, not so much because of the attractiveness of the Pavlovian conception but because of the lack of a widely accepted alternative. The present procedures do not distinguish between an underlying Pavlovian process and alternative underlying explanations.

Although autoshaping experiments and Lewis and Stoyak's (1979) signal-control experiment both produce elicited pecking, they differ in several ways. Unlike autoshaping, signal-control procedures employ prior key-peck training, response-dependent reinforcement, and the effective use of diffuse stimuli (Lewis & Stoyak, 1979; Lopatto & Lewis, 1985; Shellenberger & Lewis, 1988). Even though signal control and autoshaping produce elicited pecking that appears to be similar, the procedural differences are important because the differences imply that elicited pecking can occur in a wide variety of circumstances.

Elicited pecking may be present in chain schedules because they involve stimulus-reinforcer pairings similar to those found in the autoshaping and signal-control procedures.

Both autoshaping and signal control involve the development of pecking behavior when stimuli are paired repeatedly with reinforcers. In the initial link of a two-component chain, the first discriminative stimulus is followed by conditioned reinforcers and a primary reinforcer. These stimulus-reinforcer pairings may produce elicited pecking in the presence of the initial discriminative stimulus, much as they do in the autoshaping and signal-control experiments.

What is at issue in the analysis of chain schedules is whether the stimuli identifying the components are serving as discriminative stimuli for subsequent primary and conditioned reinforcers or if the stimuli identifying the components are eliciting responses due to their pairing with subsequent primary reinforcers or conditioned reinforcers. Is it the eliciting property or the discriminative property that is producing the pecking? The autoshaping and signal-control experiments provide evidence that leads us to expect that there may be elicited responses involved in chain schedules.

The two present experiments were intended to provide evidence for the view that elicited pecking is involved in chain schedules by using an omission procedure similar to the one reported by D. Williams and Williams (1969) and by Lewis and Stoyak (1979). Here, in Experiment 1, responding in the presence of the first component of a chain schedule omitted the subsequent component and the grain reinforcer. Our reasoning was that if responding in the early component of the chain could be maintained even when it had the effect of omitting the final component—the conditioned reinforcer—it would be evidence in favor of the possibility that elicited pecking is involved.

EXPERIMENT 1

Experiment 1 included two groups of pigeons: Group 1 participated in our preliminary investigation, and Group 2 participated in a follow-up study, conducted several months later, to provide additional support for the presence of nonreinforced key pecking in the initial link of our chaining experiment.

METHOD

Subjects

Seven White Carneau pigeons served; each was experimentally naive. They were main-

tained between 75% and 80% of their free-feeding weights for 3 weeks prior to key-peck training and during the experiment. Fresh water and grit were always available in their home cages.

Apparatus

A BRS/LVE experimental chamber (49 cm long, 36 cm high, and 36 cm wide) was used. On the front wall, two response keys (2 cm in diameter) were mounted 15 cm apart and centered 22 cm above the chamber floor. The left key, which was not used, remained dark. The right key required a force of 0.10 N for operation and could be illuminated either red, green, blue, yellow, or white. A Gerbrands grain hopper (Model 8) mounted in the center of the front wall 9 cm above the floor provided reinforcement. General illumination was provided either by two houselights (CM 313) mounted behind Plexiglas at the top of the front wall or, during reinforcement, by a white light mounted in the feeder opening. White noise and a ventilation fan provided 75 dB of sound that masked extraneous sounds.

Adjacent to the room with the experimental chamber was an Apple IIe® computer, which, through a Life Science Associates interfacing system (CAT 540), controlled events and recorded responses (Dougherty, 1990).

Procedure

The onset of the white noise signaled the beginning of a session, and its offset signaled the end.

Preliminary key-peck training. Each pigeon was trained to approach the feeder and eat grain. Pigeons were then trained to peck the right response key by the method of successive approximations (Ferster & Skinner, 1957). The response key remained white during key-peck training. On the day following the acquisition of key pecking, each pigeon began 8 days of preliminary training; the schedules included both continuous (CRF) and variable-interval (VI) reinforcement schedules. Two sessions of each of the following schedules were given (in order): CRF, VI 5 s, VI 15 s, and VI 30 s. Daily sessions lasted until 30 reinforcers were given.

Response-dependent chain. Each trial began with a 6-s fixed-interval (FI) schedule (FI 6 s). The right key was illuminated for 6 s, then darkened. Responses made while the keylight

was on had no scheduled effect. The first response following the keylight's offset produced the terminal link: The right key was then illuminated a different color. In the presence of this last keylight, grain was available on an FI schedule. Two different fixed intervals in the terminal link were investigated: 1 s and 6 s. When the reinforcer was available, the keylights and houselights were turned off, and the hopper light was turned on. The trial terminated after a single reinforcer; then the next intertrial interval began.

Omission-contingent chain. As in the response-dependent chain condition, each trial began with an FI 6-s schedule signaled by a keylight, but an omission contingency was in effect. The terminal link followed only when no response was recorded during the initial keylight presentation. If a response was made during the initial keylight presentation, the key was darkened following the 6-s keylight, the trial terminated without reinforcement, and the next intertrial interval began.

Group 1. Group 1 contained 4 pigeons, each of which were exposed to both experimental conditions. The orders of exposure were counterbalanced between pigeons; 2 each were assigned randomly to begin in one of the two experimental conditions. The colors of keylights were also balanced: Pigeons 693 and 419 received red (S2) followed by green (S1), and Pigeons 590 and 172 received green (S2) followed by red (S1). Trials were presented to the pigeons on a 90-s variable-time schedule (VT 90); intertrial intervals were multiples of 6 s and ranged from 30 s to 150 s. All values were represented equally. Pigeons remained in a condition for a minimum of 10 sessions and until stable responding was observed; our criterion was three consecutive daily data points that did not show an upward or downward trend and did not differ by more than 15%.

Rate of responding (pecks per minute) and the percentage of periods with a peck (PPP) were recorded during the initial 6-s keylight presentations. PPP was defined as the percentage of trials in which at least one response was made during the signal (the initial 6-s keylight presentation). The intertrial periods were divided into 6-s control periods; both rates of responding and PPP were recorded during control periods.

Group 2. The reasons for including Group 2 were twofold: (a) to strengthen our hypoth-

esis of nonreinforced key pecking in chain schedules by using more subjects and (b) to rule out an alternative explanation for the results obtained for Group 1. It could be argued that the comparisons, in Group 1, between the responding during the initial-link periods and control periods are confounded. The differences between the numbers of responses maintained by the S2 and by the control periods could have been due to differences in stimulus intensity. The observed differences in responding during the S2 (a lit key) and the control periods (a dark key) may have been due to differences in stimulus generalization. Responses may generalize to the lit key more than to the dark key. It may also be argued that the comparisons between the number of pecks obtained during the S2 and the number of pecks recorded across the control periods were biased because the control periods were taken across the entire intertrial interval, whereas the S2 measured responses for only a 6-s period. If the number of responses were distributed unevenly across the intertrial interval, with more responses occurring toward the end of the interval, the comparison would not be accurate.

These alternative explanations were investigated by making minor changes in the omission condition. Three pigeons were exposed to only the omission-contingent chain with the terminal link's FI value fixed at 6 s. Three specifics of this condition were altered: First, the intertrial intervals were lit by a white keylight; second, the control periods were taken from the 6 s immediately preceding the S2 (responses were also recorded during the entire intertrial period in a manner similar to Group 1); and third, the colors of the keylights were changed. The colors of the keylights signaling the S2 and the S1 were varied for different pigeons: Pigeon 102 received blue (S2) followed by yellow (S1), and Pigeons 103 and 590 received yellow (S2) followed by blue (S1).

RESULTS

For both groups, pecks were recorded throughout all trials and all intertrial intervals; all pigeons met our stability criterion. We calculated two dependent variables: percentage of periods with a peck (PPP) and rate of responding. For both groups, each session's data were examined by dividing all intertrial intervals and all S2 presentations into 6-s periods—the intertrial periods served as control

periods. In addition, Group 2's data were examined by using the control period immediately preceding the S2. The PPP provided information about a pigeon's tendency to go to the key and begin pecking. By counting the number of pecks during each period we calculated rates of responding, which provided a measure of the strength of control over the key-pecking response maintained by stimuli. Rate of responding and PPP provided similar but conceptually different information about signal-controlled responding.

Percentage of Periods with a Peck

Group 1. The analysis of PPP indicated that the S2 controlled responding in both omission-contingent and response-dependent conditions. The PPP was high during the S2 periods and low during control periods. The PPP in the response-dependent condition, using the last three session means, ranged between 95% and 100% when the S1 was 1 s long and between 93% and 100% when the S1 was 6 s long.

During omission-contingent conditions pigeons responded in the majority of S2 periods—omitting reinforcement. The PPP was lower in the omission-contingent condition than in the response-dependent condition, but the mean PPP remained high in the omission condition. The PPP in the omission-contingent conditions, again using the last three session means, ranged between 70% and 83% when the S1 was 1 s long and between 71% and 84% when the S1 was 6 s long. Each pigeon's PPP for each session and each condition is shown in Figures 1 and 2. Pigeons responded much less often during control periods than during the S2 periods; means for the control periods, for the last three sessions, were all below 25%.

Group 2. For Group 2, the PPP was very similar to that obtained from Group 1; these results are shown in Figure 3. The omission-contingent (6-s) condition yielded similar PPP averages. Mean PPP during the last three sessions ranged from 82% to 96% during the S2. The number of responses recorded during the intertrial periods, when signaled by a white keylight, was lower than that obtained in Group 1. Pigeons seldom made responses during the intertrial intervals after the first few sessions. During the last three sessions, none of the pigeons emitted a response during any intertrial period.

Rate of Responding

Group 1. Key-pecking rates yielded conclusions similar to the PPP analysis. Like the PPP measures, key-pecking rates were higher during the S2 periods than during control periods; as a group, rates of responding did not differ when the duration of S1 was 1 s or 6 s within the response-dependent or omission-contingent conditions. Omission contingencies again reduced the pigeons' tendency to respond.

The last three sessions in each condition were used to calculate the mean responses per minute. Mean rates of responding in the response-dependent conditions ranged from 18 to 109 responses per minute when the S1 was 1 s long and from 25 to 112 responses per minute when the S2 was 6 s long; these means are shown in Figure 4. Like the PPP measurements, omission contingencies influenced the rate of responding maintained by the S2. Rates of responding were lower in the omission-contingent condition than in the response-dependent condition. Mean rates of responding in the omission-contingent conditions ranged from 13 to 30 responses per minute when the S2 was 1 s long and from 13 to 38 responses per minute when the S2 was 6 s long. All birds responded at higher rates in the response-dependent conditions than in the omission conditions.

Group 2. Rates of responding for Group 2 were similar to those obtained by Group 1. Mean responses per minute in the last three sessions ranged from 13 to 43 responses per minute during the S2, and the rates of responding were zero during the intertrial intervals.

EXPERIMENT 2

Experiment 2 investigated omission responding using a schedule that more closely resembled traditional chaining procedures than the schedules in Experiment 1. The durations of the components in the chain were increased and the duration of the intertrial intervals was decreased. The contingency requirements in the initial link were also manipulated.

METHOD

Subjects and Apparatus

Six White Carneau pigeons, each naive, were maintained in an identical manner to those in

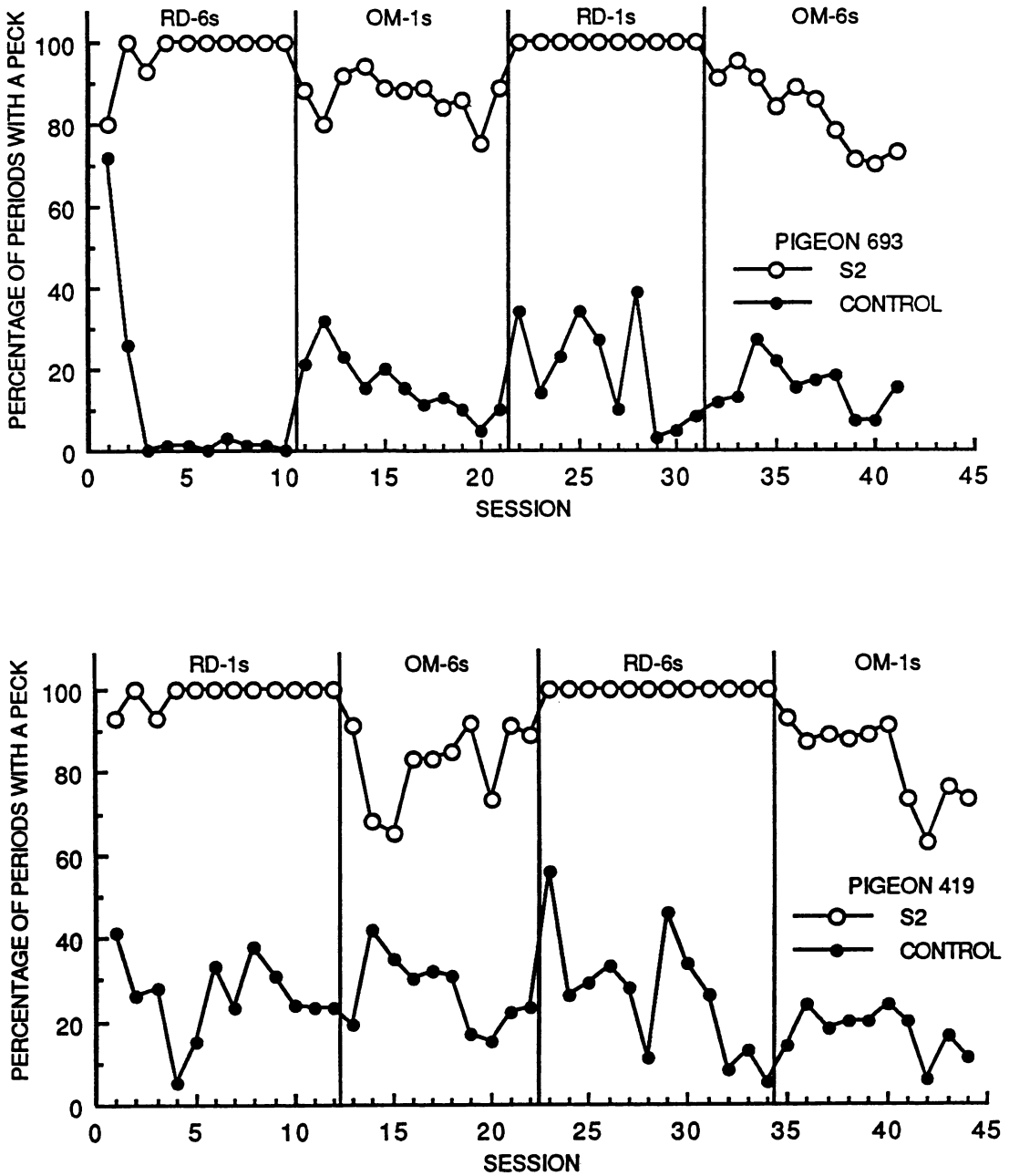


Fig. 1. Signal-controlled responding in the initial link of a two-component chain schedule is shown for Pigeons 693 (top) and 419 (bottom). Depicted are the pigeons' mean percentage of initial link (S2) periods and mean percentage of control periods, with at least one peck occurring (PPP) for each session. Sessions and conditions are shown in order of their presentation. Two conditions are shown: response dependent (RD) and omission contingent (OM); both pigeons began the experiment in a response-dependent condition. For both conditions, the second link's FI requirement was varied (1 s or 6 s). In the response-dependent condition, pecks during the S2 had no scheduled effect and were only recorded; in the omission-contingent condition, any key peck during the S2 periods canceled both the S1 and the grain reinforcer.

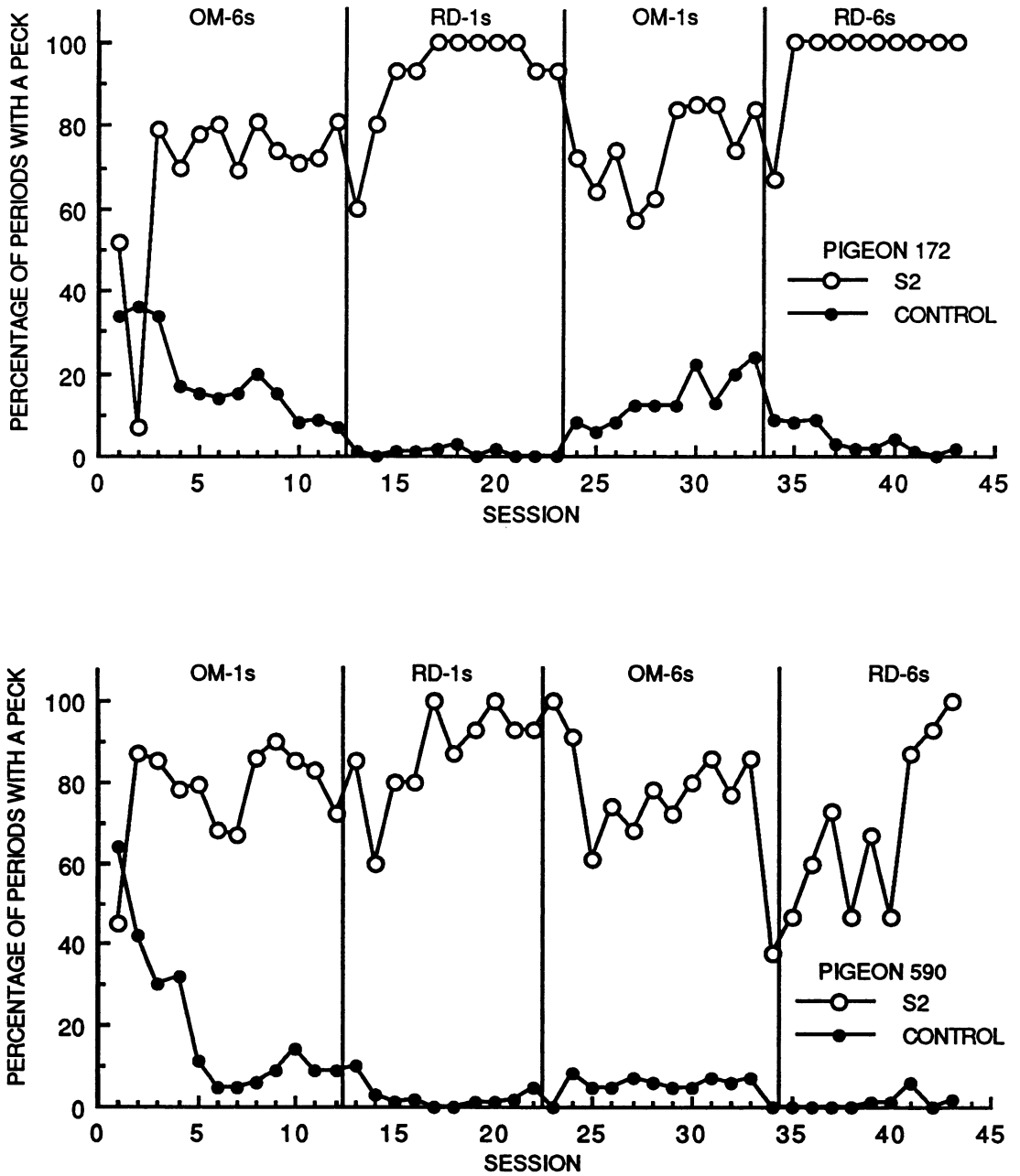


Fig. 2. Signal-controlled responding in the initial link of a two-component chain schedule is shown for Pigeons 172 (top) and 590 (bottom). Depicted are the pigeons' mean percentage of initial link (S2) periods and mean percentage of control periods, with at least one peck occurring (PPP) for each session. Sessions and conditions are shown in order of their presentation. Two conditions are shown: response dependent (RD) and omission contingent (OM); both pigeons began the experiment in an omission-contingent condition. For both conditions, the second link's FI requirement was varied (1 s or 6 s). In the response-dependent condition, pecks during the S2 had no scheduled effect and were only recorded; in the omission-contingent condition, any key peck during the S2 periods canceled both the S1 and grain reinforcer.

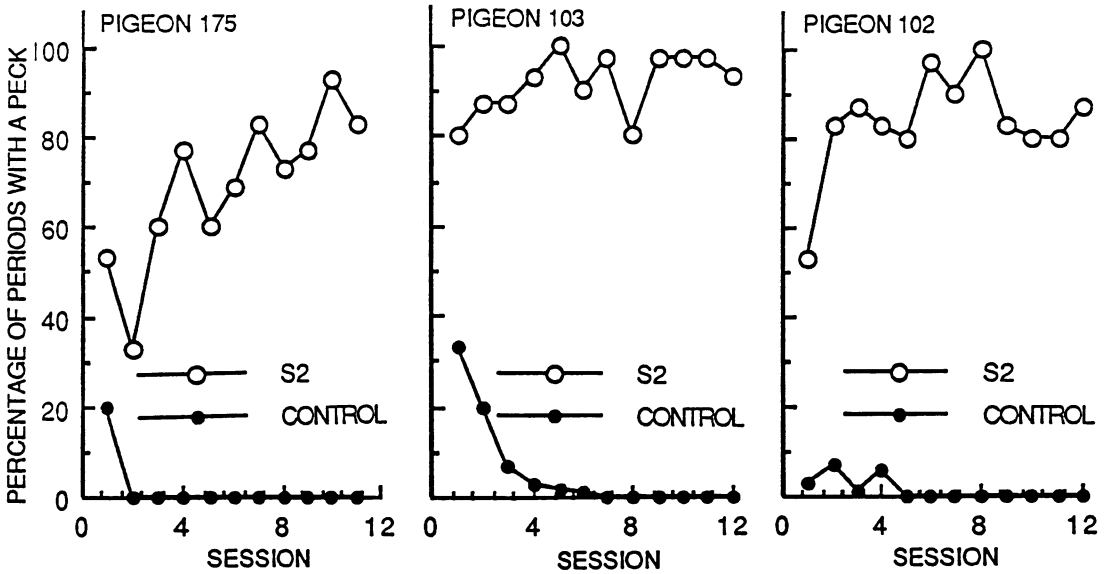


Fig. 3. Percentage of periods with a peck made by pigeons in Group 2 to the initial link in a two-link omission chain schedule; both the initial link and terminal link were FI 6 s. Responses made in the initial link before 6 s had elapsed canceled the terminal link and reinforcement. Pigeons omitted the terminal link and reinforcement often by responding during a high percentage of initial links.

Experiment 1. The apparatus was the same as that used in Experiment 1.

Procedure

After completing a preliminary training procedure like the one described in Experiment 1, all 6 pigeons were exposed to three conditions: response independent, response dependent, and a normal chain. The response-independent and response-dependent conditions both included an omission contingency. The normal chain did not include an omission

contingency. In all conditions, the terminal link's requirement was an FI 60-s schedule.

Response-independent condition. Each trial began with a 60-s initial link signaled by a keylight. No response was necessary to produce the terminal link. If a response was recorded during the initial link, the trial was terminated and the next intertrial interval began. The terminal link followed only when no response was made during the initial 60-s keylight. When the terminal link did follow, it was correlated with a different keylight, and 4-s access to grain was available on an FI 60-s schedule.

Response-dependent condition. Like the response-independent condition, an omission contingency was used, but a response was required to produce the terminal link. Responses occurring before 60 s had elapsed terminated the trial in a manner similar to the above procedure. After 60 s, if a response was not made, the keylight remained lit until a response occurred. This response produced the terminal link (the FI 60 s), signaled by a different keylight, and terminated in 4-s access to grain.

Normal chain. This condition was a standard FI 60 s in the initial link, followed by another FI 60 s in the terminal link. Each link was signaled by a different keylight.

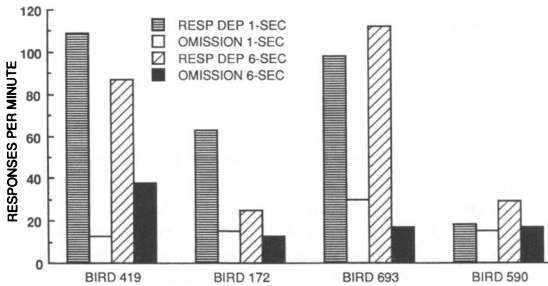


Fig. 4. Mean rates of responding made by pigeons in Group 1 during the initial link in both the response-dependent and omission-contingent conditions. The terminal link was either 1 s or 6 s.

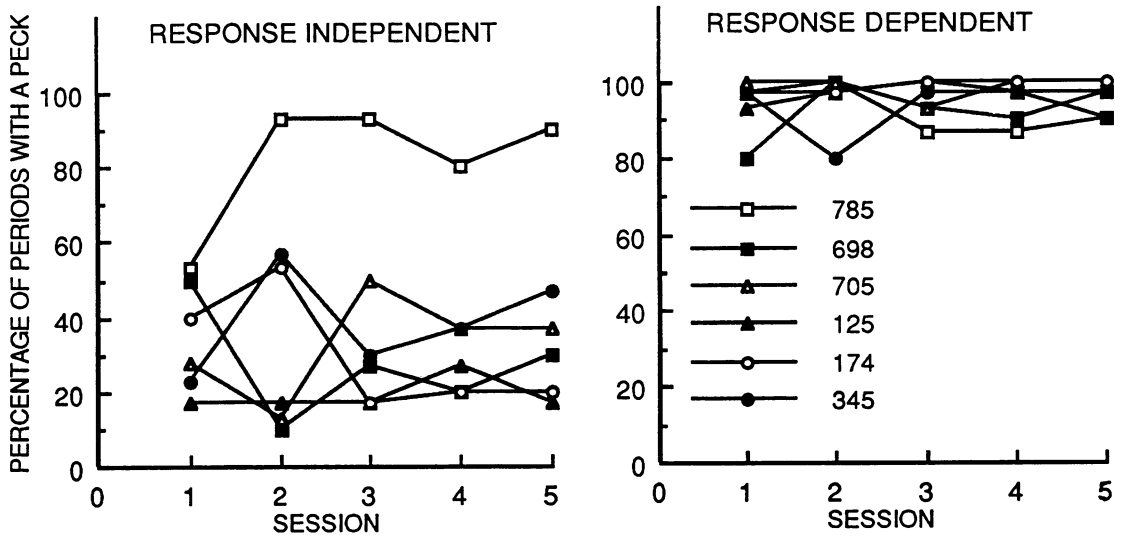


Fig. 5. Percentage of periods with a peck during the initial link of a two-link chain made by 6 pigeons in the response-independent and response-dependent conditions. Both conditions were variations of an FI 60-s FI 60-s chain; both had an omission contingency. Any response made before 60 s had elapsed in the initial link prevented the terminal link and reinforcer. The two groups differed in that no response was required to produce the terminal link in the response-independent condition; it occurred automatically. In the response-dependent condition a response was required to produce the terminal link; it did not occur automatically. Pigeons omitted the terminal link and reinforcer on a majority of trials in the response-dependent condition. Compared to the response-dependent condition, pigeons omitted fewer terminal links and reinforcers in the response-independent condition, although PPP remained high. In a third condition (not shown), the normal-chain condition, pigeons' PPP were 100% during the last five sessions.

Three pigeons began in the response-independent condition, and 3 began in the response-dependent condition. Pigeons remained in each of these conditions for at least 30 days and met the same stability criterion used in Experiment 1. The color of the key-lights was counterbalanced: 3 pigeons received blue (S2) followed by yellow (S1), and 3 received yellow (S2) followed by blue (S1). Sessions lasted until 30 trials had been presented. Each trial was separated by an intertrial period (during which the response key was white). Intertrial intervals were short, averaging 30 s, with a range from 15 s to 45 s.

RESULTS

Percentage of Periods with a Peck

Mean PPP was calculated using the mean of the last five sessions for each pigeon; these results are shown in Figure 5. With one exception, mean PPP was higher in the response-dependent condition than in the response-independent condition. Pigeon 785 was the exception; its averages were 88% in both con-

ditions. Mean PPP in the response-independent condition for Pigeons 785, 698, 705, 125, 174, and 345 was 88%, 26%, 41%, 20%, 19%, and 38%, respectively. Mean PPP in the response-dependent condition for Pigeons 785, 698, 705, 125, 174, and 345 was 88%, 93%, 97%, 96%, 100%, and 97%, respectively. During the normal chain condition, pigeons emitted at least one peck during all periods; PPP was 100% in all cases.

Rate of Responding

Results for rates of responding were similar to the PPP results. Rates were lowest in the response-independent condition, higher in the response-dependent condition, and highest in the normal-chain condition. The rates of responding obtained from each pigeon during the last five sessions in each condition are presented in Figure 6. Across all pigeons, rates of responding averaged 2.2 responses per minute in the response-independent condition, 10.5 responses per minute in the response-dependent condition, and 22.3 responses per minute in the normal-chain condition.

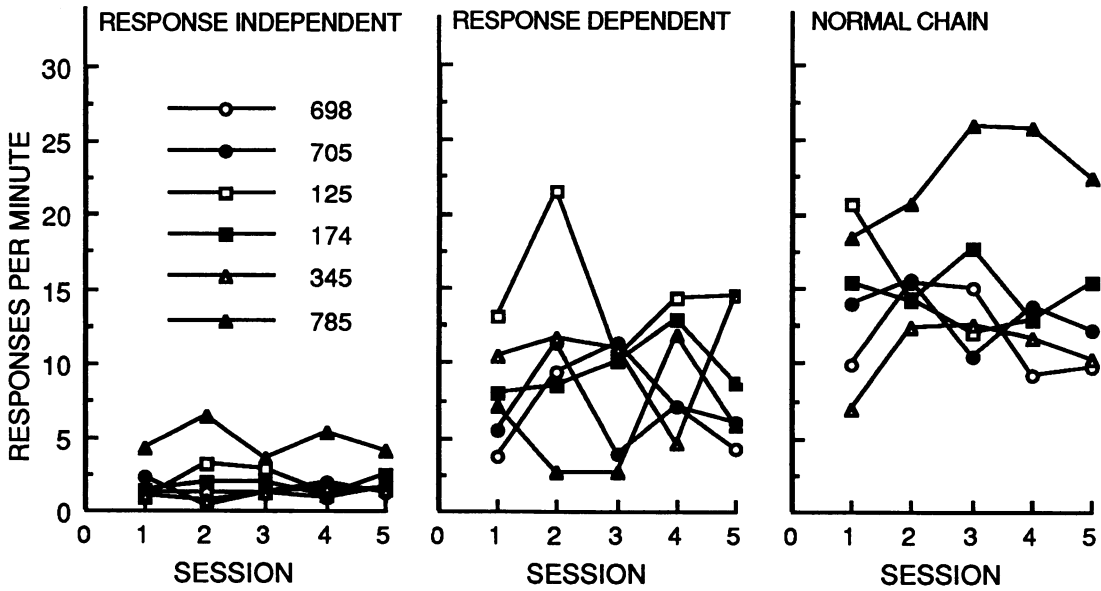


Fig. 6. Rates of responding during the initial link of a two-link chain made by 6 pigeons in three chaining conditions: response independent, response dependent, and normal chain. All conditions were variations of a two-link chain; all had FI 60-s schedules in both the initial and terminal links. The first two conditions, response independent and response dependent, had an omission contingency requirement: Responses made before 60 s had elapsed in the initial link canceled the terminal link and reinforcer. In the response-independent condition, no response was required to produce the terminal link; it occurred automatically. In the response-dependent condition, a response was required to produce the terminal link; it did not occur automatically. The last condition, the normal chain, was a standard FI 60-s FI 60-s chain. Rates of responding were lowest (in the response-independent condition) when a response was not required to produce the terminal link and were higher in the response-dependent condition when a response was required. Rates of responding were highest in the normal-chain condition when the omission contingency was not present.

DISCUSSION

The data from both Experiment 1 and Experiment 2 support our contention that elicited pecking is involved to some extent in chain-schedule experiments using pigeons as subjects. In Experiment 1, elicited pecking was evident in both the response-dependent and omission-contingent conditions, but the strongest evidence was from the omission-contingent conditions. During the omission procedures, each key peck during the initial link omitted the terminal link and omitted the reinforcer. Yet, during the last five sessions in the omission conditions, pigeons responded during 78% of the initial links, canceling reinforcement 78% of the time; pigeons responded during only 13% of the corresponding control periods. The initial-link responding is consistent with our hypothesis that elicited pecking is involved in the chaining paradigm.

The results from the response-dependent condition also support our contention. During

the last five sessions in the response-dependent conditions, pigeons responded during 97% of the initial links even though these responses were not necessary to produce the terminal link or the reinforcer. Pigeons responded during only 8% of the corresponding control periods. Only a single key peck following the offset of the initial-link keylight was necessary to produce the next link; however, pigeons responded during a high percentage of the initial links. These results are difficult to interpret using the concept of contingent conditioned reinforcement alone.

Why do the pigeons peck during the early components of a chain in the omission procedures? Traditionally, chaining is analyzed using three terms: discriminative stimuli, conditioned reinforcers, and unconditioned reinforcers (Ferster & Skinner, 1957; Keller & Schoenfeld, 1950). Using the traditional approach, during the omission procedures of Experiment 1 the offset of the initial-link stimulus should serve as a discriminative stimulus

to respond and the initial-link stimulus as a stimulus not to respond. Responses made before the initial link's temporal requirement had passed terminated the rest of the chain. Only when the pigeon failed to peck during the initial link itself and pecked the keylight that followed did the second link and then, later, the reinforcer appear. Responding during the initial-link stimulus should have been eliminated; the reinforcing properties produced by the occurrence of the second link or by the occurrence of the primary reinforcer never followed responses during the initial link. Responding before 6 s had elapsed was not reinforced by the appearance of the second link or the primary reinforcer. Yet pigeons responded during a high percentage of the initial links and at high rates.

In Experiment 2, using a schedule that more closely resembled traditional chaining procedures, longer components, and shorter intertrial intervals, parallel results were obtained. Again, pigeons made responses during a high percentage of the initial links, canceling the subsequent link and reinforcement. The PPP and rates of responding were higher in the response-dependent condition than in the response-independent condition: PPP during the initial link (using the last five sessions) averaged 39% in the response-dependent condition and 95% in the response-independent condition.

An account of the omission responding may be that the chaining paradigm inherently tends to produce conditions conducive to elicited pecking. Because we cannot distinguish between autoshaping and signal-control contingencies in the present experiment, we refer to the results of both of them as elicited pecking. Essential to the chaining process is the repeated pairing of stimuli and response-dependent reinforcers; these pairings may contribute to the development of elicited pecking. Each stimulus that is repeatedly presented before a primary reinforcer may acquire reinforcing properties (i.e., become a conditioned reinforcer; Kelleher, 1966). At the same time, the stimulus may acquire eliciting properties.

There are several ways one could attempt to dismiss the relevance of elicited pecking to the behavior in chain schedules. One is to point out that the time intervals typically used in the elicited pecking experiment are different from the time intervals used in chain schedules. Sec-

ond, the elicited pecking is normally observed using keylight stimuli, and behavior chains can be developed using other stimuli. Third, chain schedules involve contingent reinforcement and autoshaping involves reinforcement presented noncontingently. Attempts to dismiss elicited pecking for these reasons seem to us unconvincing.

It could be argued that the present results are not relevant to the analysis of chain schedules, or to the operation of conditioned reinforcement in those schedules, because the time intervals in the present experiment were too short. After all, the intervals in Experiment 1 correspond more closely to the intervals used in autoshaping experiments; it could be argued that these are relevant only to those experiments, even though the contingencies were close to those in chain schedules. The durations of schedule components in Experiment 1 were brief: 6 s or 1 s. In most of the research on chain schedules, component durations were several minutes long (Kelleher & Gollub, 1962).

Elicited pecking is, however, observed using sequences of stimuli similar in length to those found in chain-schedule research. In Experiment 2, many pecks were maintained in long schedules with long intervals. Other researchers have reported similar observations. Ricci (1973), for example, studied autoshaping in procedures with stimuli that roughly corresponded to the length of intervals commonly used in experiments on chain schedules. In Ricci's experiment, a sequence of colored keys (red, yellow, blue, and green) preceded grain. Each stimulus was 30 s long. Ricci found substantial pecking during these stimuli, even though the grain occurred independent of pecking. Further, the relative frequency of responding in the earlier components of the stimulus sequences was similar to what occurs in chain schedules (Gollub, 1958; Kelleher & Fry, 1962; Staddon, 1983). The frequency of responding was lowest in the stimuli most distant from the reinforcer and increased as the time of the reinforcer approached.

In addition, all chain schedules using long intervals contain many shorter intervals that may acquire stimulus control. Even if the eliciting responses are present in great numbers only because the relationships that occur as a result of the short time intervals, there still may be many elicited responses. In schedules

with long intervals, there are moments when short intervals come into play: long time intervals contain short time intervals. One example is the analysis of fixed-interval schedules. It is widely recognized that the early part of a fixed-interval schedule can serve as an S— for the occurrence of reinforcement. In the same sense in which the early part of an FI schedule can serve as an S— for reinforcement at the end of the interval, there are points in every chain schedule in which short intervals can acquire stimulus properties.

The possible involvement of autoshaping as an explanation for chain-schedule behavior may be discredited by showing that the chain behavior occurs when stimuli other than key-lights are used (e.g., auditory stimuli). Auditory stimuli work poorly or not at all as stimuli in autoshaping procedures (Schwartz, 1973). Because signal control occurs readily in the presence of auditory stimuli (Lewis & Stoyak, 1979) and in the presence of other diffuse stimuli (Lewis & Stoyak, 1979; Shellenberger & Lewis, 1988), elicited pecking is still plausible in many situations.

Elicitation might be dismissed as irrelevant to the understanding of chain schedules because chain schedules involve contingent reinforcers and autoshaping involves the non-contingent delivery of reinforcers. The chain contingencies result in stimuli paired with reinforcers, but it could be argued that, in chain schedules, the response contingency alters or interferes with the autoshaping of responses. This objection is weakened by the strength of elicited control of key pecking observed in the signal-control experiments. In the signal-control experiments, stimuli paired with response-contingent reinforcers come to elicit key pecking.

At issue, of course, is not just the analysis of chain schedules. The concepts of conditioned reinforcement and discriminative stimuli are pervasive in the experimental analysis of behavior, and the possibility of chain stimuli eliciting responses makes it relevant to most operant analyses. The present manipulations are not so unambiguous as to rule out interpretations other than elicitation. But they do raise questions. Why do the responses occur in the presence of the component stimuli? Is it because of the discriminative property of the stimulus or the eliciting property of the stimulus? If it is the discriminative property of the

stimulus, the property must have developed as a result of the stimulus setting the occasion for reinforcers that follow the discriminative stimulus. In the present experiment, these consequences were omitted—a procedure that supports the possibility that chain schedules of reinforcement, with pigeons as subjects, involve many elicited key pecks.

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